# Using Composite Material to Fabrication UAV Wing

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ISTAS FAHRURRAZI NUSYIRWAN
MD NIZAM DAHALAN

FAKULTI KEJURUTERAAN MEKANIKAL
UNIVERSITI TEKNOLOGI MALAYSIA
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# Abstract

Current trend in aircraft structural design is to use composite material as primary structural elements. The objective of the project is to develop the best way to fabricate aircraft wing using composite material. The best way means the structure must have the best strength to weight ratio. This means the wing strength capacity is maintained with small weight. The benefit of using composite materials is explained in the first chapter. The project has ventured into several methods of fabrication and the best method is found being used by Eagle Aircraft (M) Sdn. Bhd. One wing was fabricated at the company and the product is compared to another wing fabricate through different method. As the conclusion, the method of fabrication plays an important role in determining the highest strength-to-weight ratio.

# Abstrak

Tren terkini dalam merekabentuk struktur pesawat adalah dengan menggunakan bahan komposit sebagai element yang utama. Objektif projek ini adalah untuk mendapatkan kaedah yang terbaik untuk menghasilkan sayap pesawat UAV dengan menggunakan bahan komposit. Ini bermakna, struktur perlulah kuat tetapi mempunyai berat yang ringan. Bab pertama menerangkan kebaikan menggunakan bahan komposit. Projek ini telah meneroka beberapa kaedah dan ternyata kaedah yang terbaik diperolehi dari pengalaman syarikat Eagle Aircraft (M) Sdn Bhd. Satu sayap telah dihasilkan di syarikat tersebut dan telah dibandingkan dengan sayap yang dihasilkan dengan kaedah lain. Ternyata, sebagai kesimpulan, kaedah pembuatan memainkan peranan yang penting dalam memberikan kekuatan yang tinggi tetapi ringan.

# CHAPTER 1

# LITERATURE SURVEY

## 1.3. Introduction

The advent of technology has lead manufacturer to fabricate aircraft components using composite materials. There many advatanges provided by composite materials. In this project, due to the advantage of composite materials, the material is selected for use to fabricate aircraft wing.

Composite materials have been utilized to solve technological problems for a long time but only in the 1960s did these materials start capturing the attention of industries with the introduction of polymeric-based composites. Since then, composite materials have become common engineering materials and are designed and manufactured for various applications including automotive components, sporting goods, aerospace parts, consumer goods, and in the marine and oil industries. The growth in composite usage also came about because of increased awareness regarding product performance and increased competition in the global market for lightweight components. Among all materials, composite materials have the potential to replace widely used steel and aluminum, and many times with better performance. Replacing steel components with composite components can save 60 to 80% in component weight, and 20 to 50% weight by replacing aluminum parts. Today, it appears that composites are the materials of choice for many engineering applications.

## 1.4. Why it is called composites?

The reason behind the word composite is because it involves two or more subtances to form a load bearing structure . In aircraft design the term compsites is used when the main material of construction consists of strands of strong fibres bind together with an adhesive commonly called matrix or resin.

Normally, composite materials are used in the form of layers of woven fibres or flat tapes, depending on its usage. These materials has its own advantage in comparison with metal, i.e. they are easily formed into complex shapes and curves. Thus producing a very smooth aerodynamic friendly finish.

In term of strength, careful design and material selection can give a stronger, stiffer and lighter than metal. For example, glider manufacturers uses composite materials to produce a beautiful and smooth surface fpr their gliders. One of the early material selected is glass fibres woven into a cloth or ply. The ply is then soaked with epoxy resin which is very strong when cured, to produce a light and strong structure.

The introduction of carbon fibre into the family have further improve in strength to weight ratio as well as rigidity. In early 1960s, composites are used in the form of uni-directional tapes. These are supplied with a measured quantity of resin already poured around the fibre, commonly known as pre-pregs. Examples of pre-pregs materials can be seen in the wings and forward fuselage of the AV-8B Harrier II and the tailplanes of the Airbus A-320. Apart from limited number of Beechcraft Starship aircraft, no all composite commercial aircraft has yet gone into production but composites are used extensively in combat aircraft like the Eurofighter 2000 and SAAB Gripen.

In this study, the feasibility of the use of all composites aircraft is carried out. This is to take advantage the availability of the composite materials and the expertise already gathered through the national CTRM Eagle Aircraft project.

## 1.5. The strength of the composite materials

A piece of composite material, such as tape, with all of its fibres positioned in parallel of each of other will be much stronger when pulled perpendicular from the strand direction. The strength is isotropic. Typical design values of tensile stress (taken from actual aircraft design manuals) are listed below, the aluminum alloys are included as comparison:

| | |
|---|---|
| Glass fibre, wet lay-up | 310 MPa |
| Carbon fibre, wet lay-up | 292 MPa |
| Carbon fibre, pre-preg | 585 MPa |
| Al-alloy 2024-T3 | 414 MPa |
| Al-alloy 2014-T651 | 460 MPa |

Further characteristic is about the strength to weight ratio. The main reason behind the selection of composites is because their strength to weigth ratio. A high strength to weigth ratio will reduce the weight of the aircraft. To get S/W, the above tensile stresses are divided by their respective density (starting with Al-alloy as 100%);

| | |
|---|---|
| Al-alloy sheet | 100% |
| Al-alloy plate | 111% |
| Glass fibre, wet lay-up | 126% |
| Carbon fibre, wet lay-up | 182% |
| Carbon fibre, pre-preg | 235% |

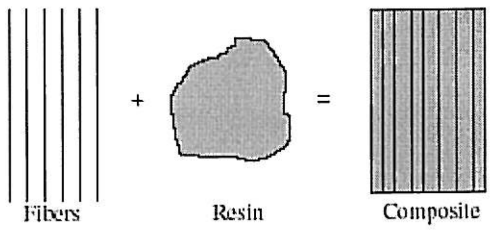



Fig 1.1 Formation of composite materials using fibers and resin.

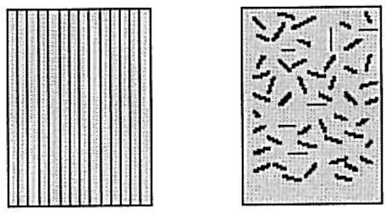



Fig 1.2 Type of commonly found composites.

## 1.6. Functions of Fibers and Matrix/Resin

A composite material is formed by reinforcing plastics with fibers. To develop a good understanding of composite behavior, one should have a good knowledge of the roles of fibers and matrix materials in a composite. The important functions of fibers and matrix materials are discussed below.

The main functions of the fibers in a composite are:

1. To carry the load. In a structural composite, 70 to 90% of the load is carried by fibers.
2. To provide stiffness, strength, thermal stability, and other structural properties in the composites.
3. To provide electrical conductivity or insulation, depending on the type of fiber used.

A matrix material fulfills several functions in a composite structure, most of which are vital to the satisfactory performance of the structure. Fibers in and of themselves are of little use without the presence of a matrix material or binder. The important functions of a matrix material include the following:

1. The matrix material binds the fibers together and transfers the load to the fibers. It provides rigidity and shape to the structure.
2. The matrix isolates the fibers so that individual fibers can act separately.
3. This stops or slows the propagation of a crack.
4. The matrix provides a good surface finish quality and aids in the production of net-shape or near-net-shape parts.
5. The matrix provides protection to reinforcing fibers against chemical attack and mechanical damage (wear).
6. Depending on the matrix material selected, performance characteristics such as ductility, impact strength, etc. are also influenced.
7. A ductile matrix will increase the toughness of the structure. For higher toughness requirements, thermoplastic-based composites are selected.
8. The failure mode is strongly affected by the type of matrix material used in the composite as well as its compatibility with the fiber.

## 1.7. Some advantage of using composite materials

Composites have been routinely designed and manufactured for applications in which high performance and light weight are needed. They offer several advantages over traditional engineering materials as discussed below.

1 Composite materials provide capabilities for part integration. Several metallic components can be replaced by a single composite component.
2 Composite structures provide in-service monitoring or online process monitoring with the help of embedded sensors. This feature is used to monitor fatigue damage in aircraft structures or can be utilized to monitor the resin flow in an RTM (resin transfer molding) process. Materials with embedded sensors are known as "smart" materials.
3 Composite materials have a high specific stiffness (stiffness-to-density ratio), as shown in Table 1.1. Composites offer the stiffness of steel at one fifth the weight and equal the stiffness of aluminum at one half the weight.

4 The specific strength (strength-to-density ratio) of a composite material is very high. Due to this, airplanes and automobiles move faster and with better fuel efficiency. The specific strength is typically in the range of 3 to 5 times that of steel and aluminum alloys. Due to this higher specific stiffness and strength, composite parts are lighter than their counterparts.

5 The fatigue strength (endurance limit) is much higher for composite materials. Steel and aluminum alloys exhibit good fatigue strength up to about 50% of their static strength. Unidirectional carbon/epoxy composites have good fatigue strength up to almost 90% of their static strength.

6 Composite materials offer high corrosion resistance. Iron and aluminum corrode in the presence of water and air and require special coatings and alloying. Because the outer surface of composites is formed by plastics, corrosion and chemical resistance are very good.

7 Composite materials offer increased amounts of design flexibility. For example, the coefficient of thermal expansion (CTE) of composite structures can be made zero by selecting suitable materials and lay-up sequence. Because the CTE for composites is much lower than for metals, composite structures provide good dimensional stability.

8 Net-shape or near-net-shape parts can be produced with composite materials. This feature eliminates several machining operations and thus reduces process cycle time and cost.

9 Complex parts, appearance, and special contours, which are sometimes not possible with metals, can be fabricated using composite materials without welding or riveting the separate pieces. This increases reliability and reduces production times. It offers greater manufacturing feasibility.

10 Composite materials offer greater feasibility for employing design for manufacturing (DFM) and design for assembly (DFA) techniques. These techniques help minimize the number of parts in a product and thus reduce assembly and joining time. By eliminating joints, high-strength structural

parts can be manufactured at lower cost. Cost benefit comes by reducing the assembly time and cost.

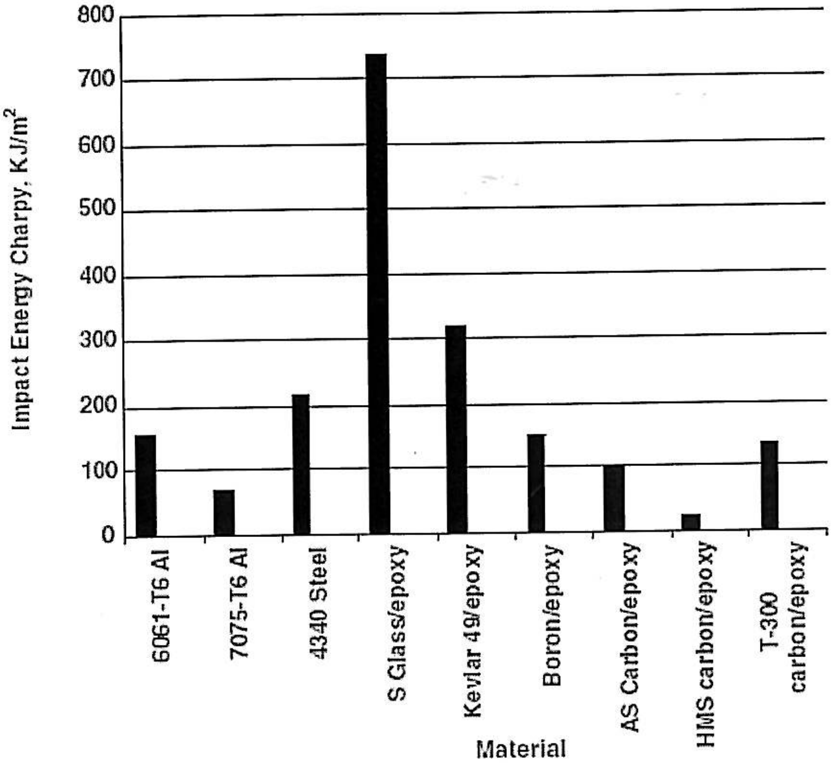



Fig 1.3. Impact properties of various engineering materials. Unidirectional composite materials with about 60% fiber volume fraction are used. ( Source: Data adapted from Mallick.[1])

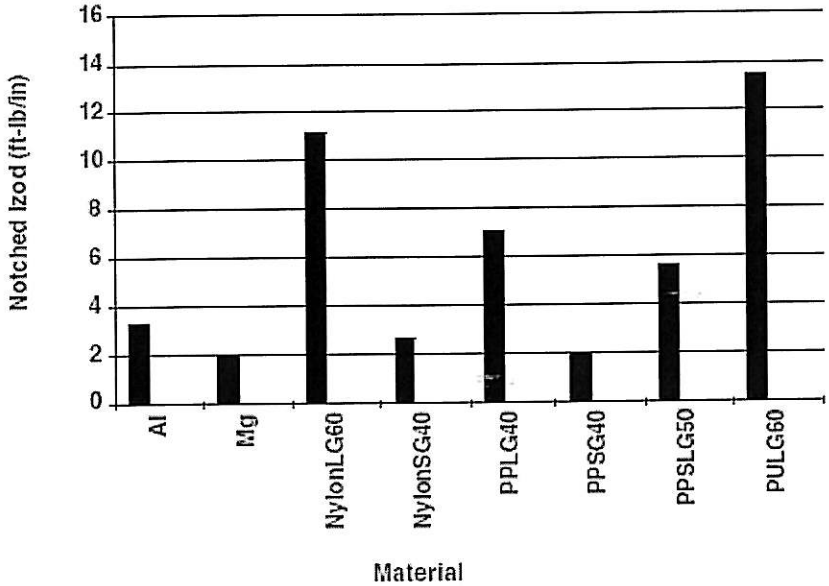



Figure 1.4 : A comparison on impact strength

Composites offer good impact properties, as shown in Figures 3, shows impact properties of aluminum, steel, glass/epoxy, kevlar/epoxy, and carbon/epoxy continuous fiber composites. Glass and Kevlar composites provide higher impact strength than steel and aluminum. Figure 4 compares impact properties of short and long glass fiber thermoplastic composites with aluminum and magnesium. Among thermoplastic composites, impact properties of long glass fiber nylon 66 composite (NylonLG60) with 60% fiber content, short glass fiber nylon 66 composite (NylonSG40) with 40% fiber content, long glass fiber polypropylene composite (PPLG40) with 40% fiber content, short glass fiber polypropylene composite (PPSG40) with 40% fiber content, long glass fiber PPS composite (PPSLG50) with 50% fiber content, and long glass fiber polyurethane composite (PULG60) with 60% fiber content are described. Long glass fiber provides three to four times improved impact properties than short glass fiber composites.

## 1.8. Composite Product Fabrication

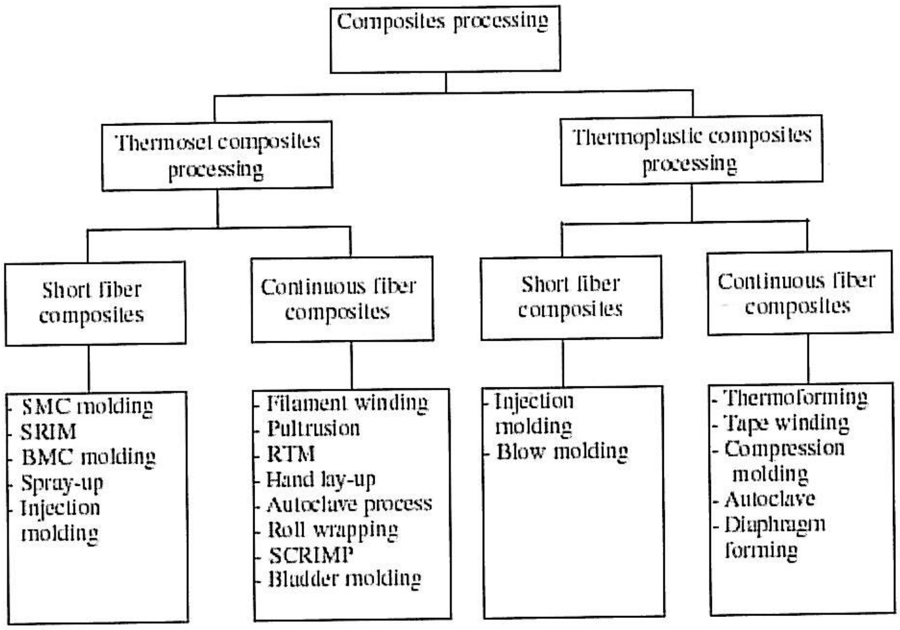



Figure 1.5 : Type of manufacturing process.

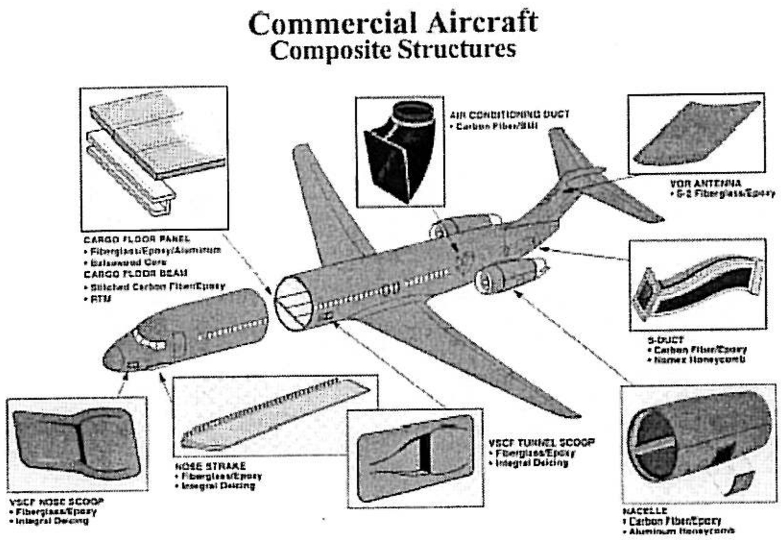



Figure 1.6 : The use of composite material on commercial aircraft.

# CHAPTER 2

# METHODOLOGY

## 2.1. The Wing

The project objective is to build a wing using composite material. This is actually a continuation of Elang-1 project. Elang-1 project is a project to build indigenous UAV meant for local use. Most UAV's in the market are build this composite material, thus we are keen to explore the possibility of using this material and to study the best method to fabricate the wing.

The wing that is going to be build is show in Figure 2.1 and 2.2 below.

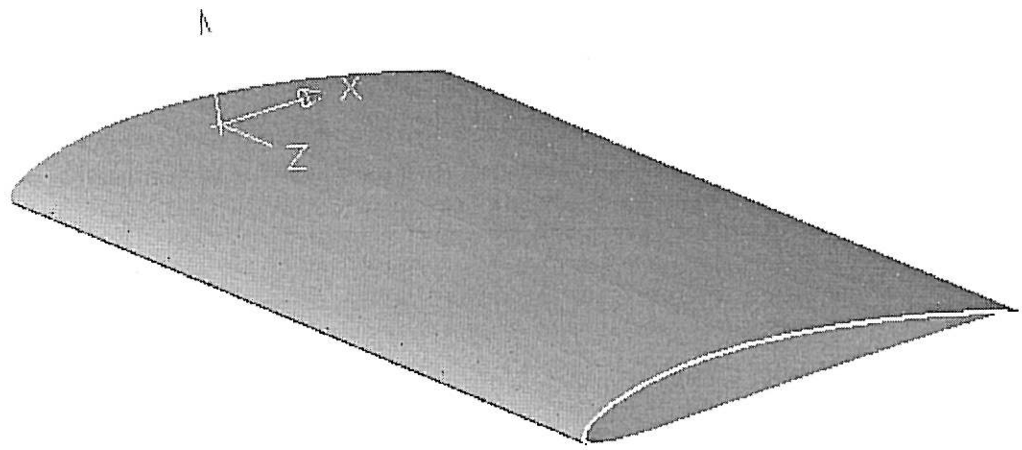



Figure 2.1 : NACA4412 – 0.63m span

Figure 2.2 : NACA 4412 airfoil cross section

Initial idea is to build a monocoque structure that is, does not require stiffener and spar. Later on, after seeing the way Eagle Aircraft (Malaysia) Sdn. Bhd. Build their aircraft is it better to have ribs and spars just to ensure the strength and durability of the wing.

The research is just aims to build the wing but not the spar. Thus it is not possible yet to run a structural test on the wing.

## 2.2. Wing Fabrication

One of the structural component of Elang-1 UAV is the wing. The research concentrates to determine the best way to fabricate UAV wing. Current trend is to use composite material to fabricate wings such as UAV.

However, to determine the best way to fabricate the wing is rather a complex matter. UTM does not have the right technical knowledge and experience in fabricating aircraft structural component using composite material up to the industrial standards.

There are several ideas arised in finding the right way to build the wing using the composite materials. Those are

To build the mould in-house and fabricate the wing in-house

1. To sub contract the mould building and fabricate in-house
2. To sub contract the mould building and subcontract the fabrication.

Unfortunately, due to lack of facilities such as

1. Vacuum facilities
2. Laminating experts
3. Mould experts and materials

it is not possible to build the mould and even fabricating the wing.

## 2.3. Airfoil selection

Previous studies were conducted to determine the type of airfoil selected for the project.

## 2.4. Fabricating the Pattern

The full scale drawing of the airfoil is produced using CAD program. Later on, the fabrication of the wing is carried out using a big lathe machine located at the MarinLab. The machine used to fabricate the wing is show in figure 2.3.

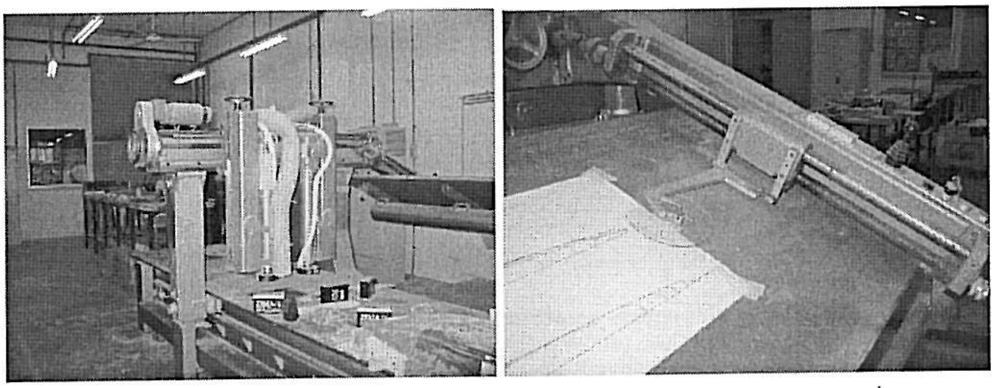


Figure 2.3 : Machine used (Courtesy from MarinLab UTM)

The mode of operation of the machine is partly automatic and partly manual. The fullscale drawing of the airfoil is placed on a special table and a block of wood sized slightly bigger than the airfoil is placed of the cutting area. A tracing mechanism is then placed on top of the drawing and a technician will manually traced the drawing lines. In doing so, the rotary cutter will cut the wood according to the drawing.

The whole process took almost two days to complete. After completion, the next stage is to sand the surface and to ensure smooth finishing, holes were filled with filler. All these work are done manually by experience technicians.

Figure 2.3a : The wing made of jelutiong wood using machine at Fig 2.3 (the green color is the primer color)

## 2.5. Building Up the Mould

A company specializing in fibre glass construction was choosen to fabricate the mould. The pattern is first sprayed using primer paint. The primer paint is meant to avoid the composite materials to bond to the pattern as well as to get a smooth finishing. The composite material used to fabricate the mould is fibre glass of woven rowing type.

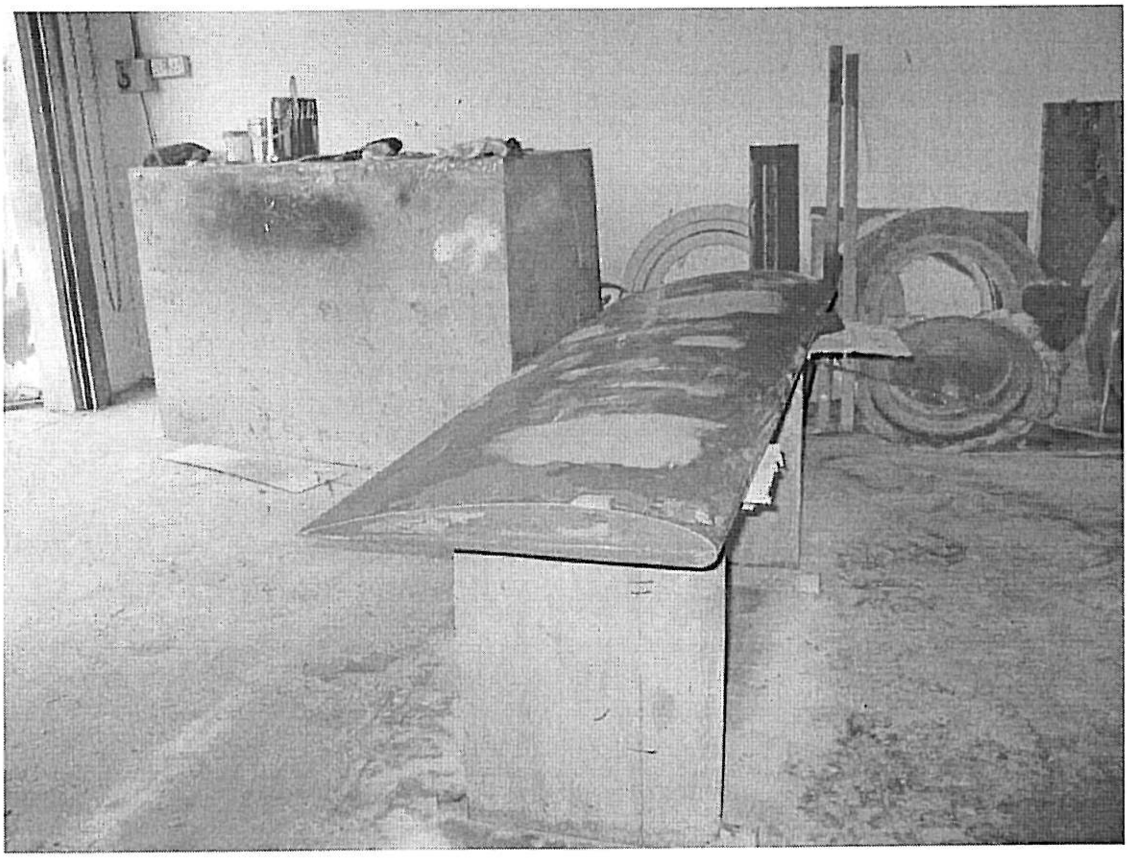


Figure 2.4: Wood pattern is painted using primer. (The none-uniform picture is because the picture was taken after mould fabrication).

The fibre glass are wet lay up on to the pattern surface. This process was done several times until an adequate thickness is achieved. This is necessary as the thickness will provide a strong support during the real model fabrication process.

The mould is divided into two sections, i.e. upper surface and bottom surface. In order to increase it's strength, additional stiffeners are installed to both moulds as shown in Figure 2.5

Figure 2.5 : Mould with stiffener.

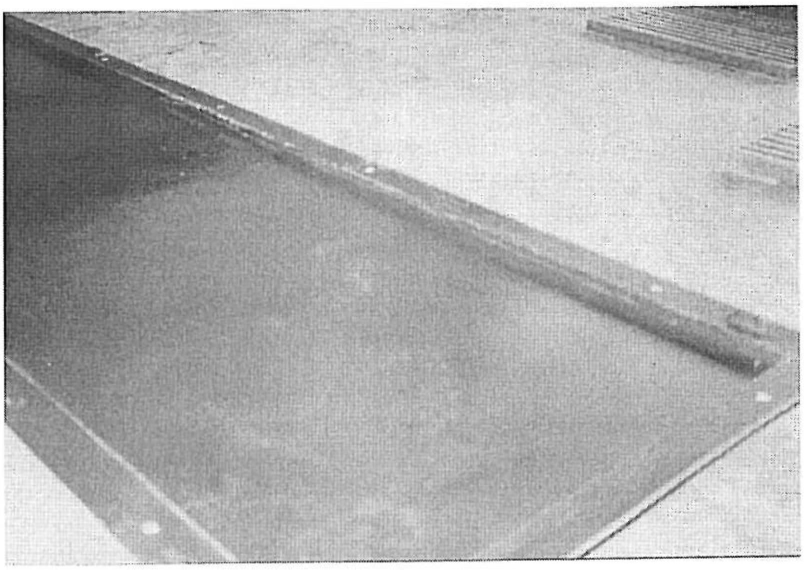


Figure 2.6 : Surfaces before buffing process.

To add to better surface finishing, sand paper with a finest grain size is applied before a process called buffing is done. Wax is then applied.

A completed mould is shown in Figure 2.7 below.

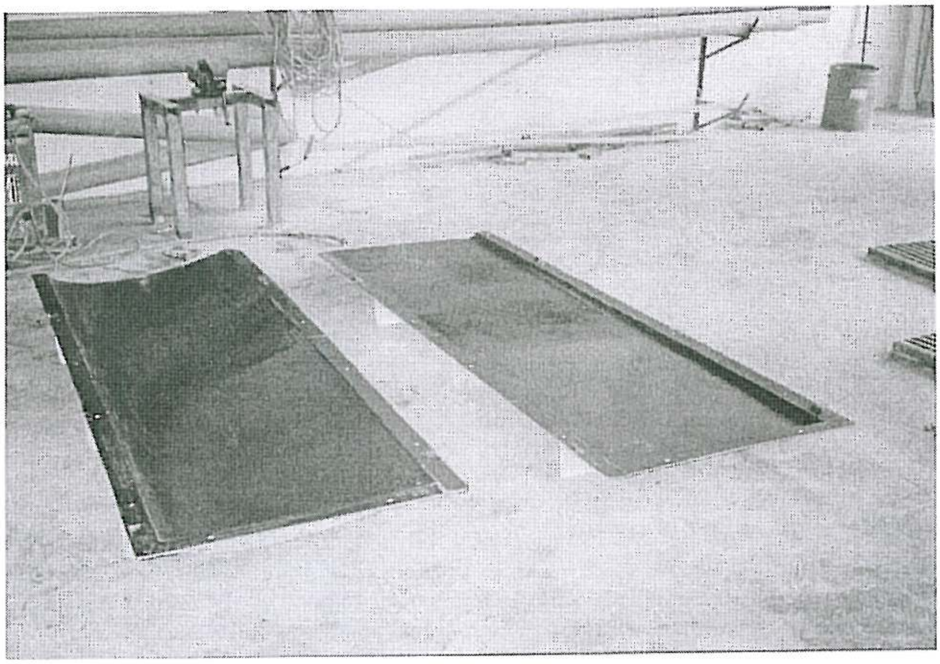


Figure 2.7 : Completed mould.

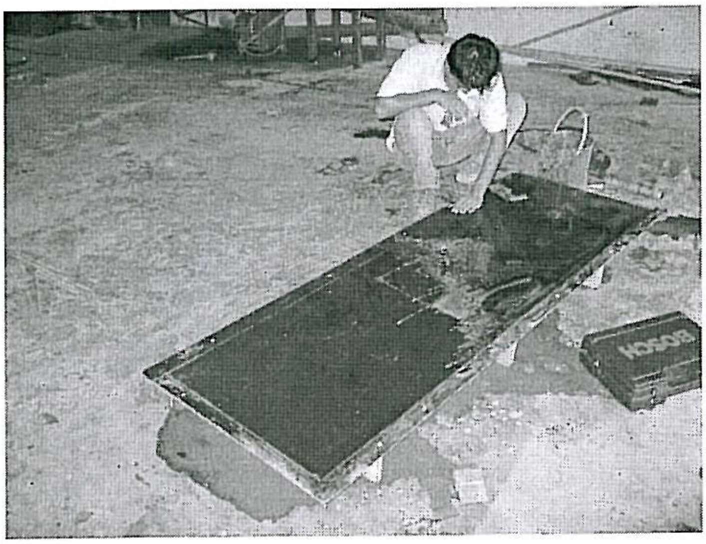


Figure 2.8 : Buffing process

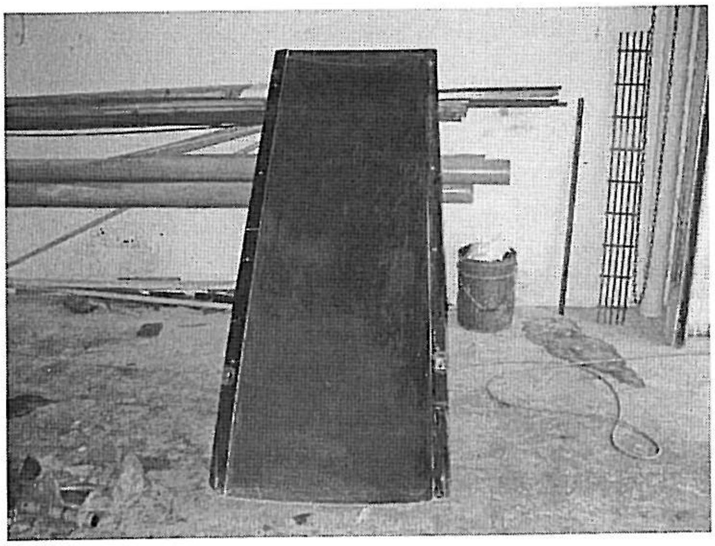


Figure 2.9 : Another looks before buffing.

Figure 2.10 : Smooth finishing after buffing and waxing.

## 2.6. Model making process

In this project we decided to have two stages of model making using the mould. Although the main idea is to produce the model using carbon-fiber material but due to the high cost, the first attempt to produce the model is to use fibre glass material. The main reason behind it is to avoid waste of material and to experience the problem arising in the model making process.

There are several ideas to fabricate the wing. Those ideas are from suggestion made by people familiar with composite material.

## 2.7. The first attempt

It is suggested that, in order to increase the strength of the wing, a foam is applied in to the wing.

The foam used have the density between 45 kg/m$^3$ to 60 kg/m$^3$. To make the foam, the moulds are bolted together. There should not be any opening once they were bolted except one small hole used to pour the foam chemicals into the mould.

The chemical contains three main components, i.e. the poly oil, iso cynide and freon R11. They are mixed according the predetermined composition.

The chemical must be poured immediately into the mould because it reacts and expand relatively fast.

If the amount of chemical is adequate and foam will expand accordingly and will provide an excellent finishing. Usually, it takes almost 24 hours to fully cured.

However, it takes three attempts before getting the right mixture and a good result. The first attempt was almost failed because the foam expansion causing big stress to the mould and causing it to crack.

Figure 2.11 :Chemical is poured into the mould

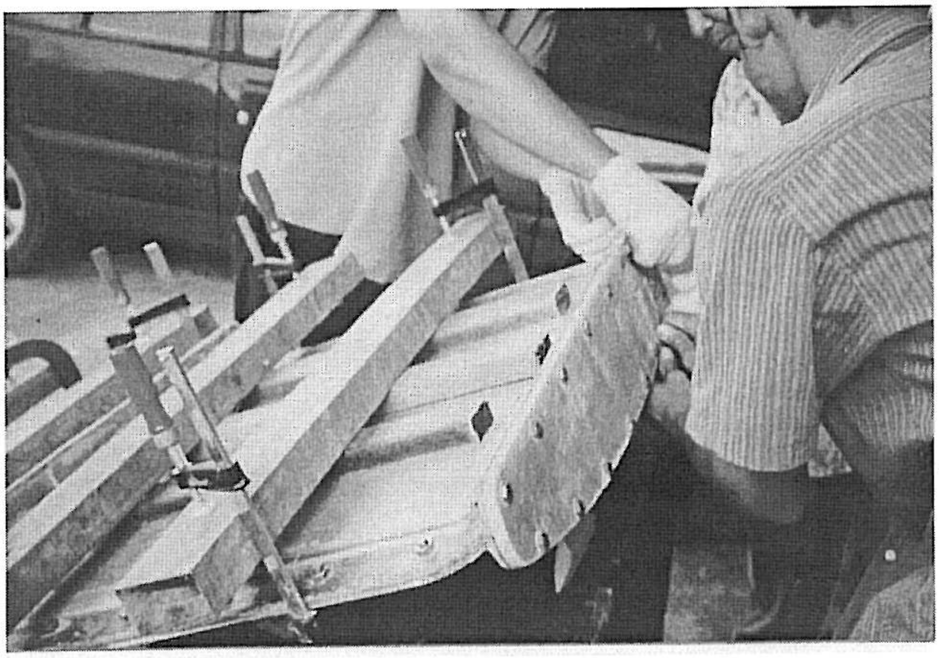


Figure 2.12: Closing all openings.

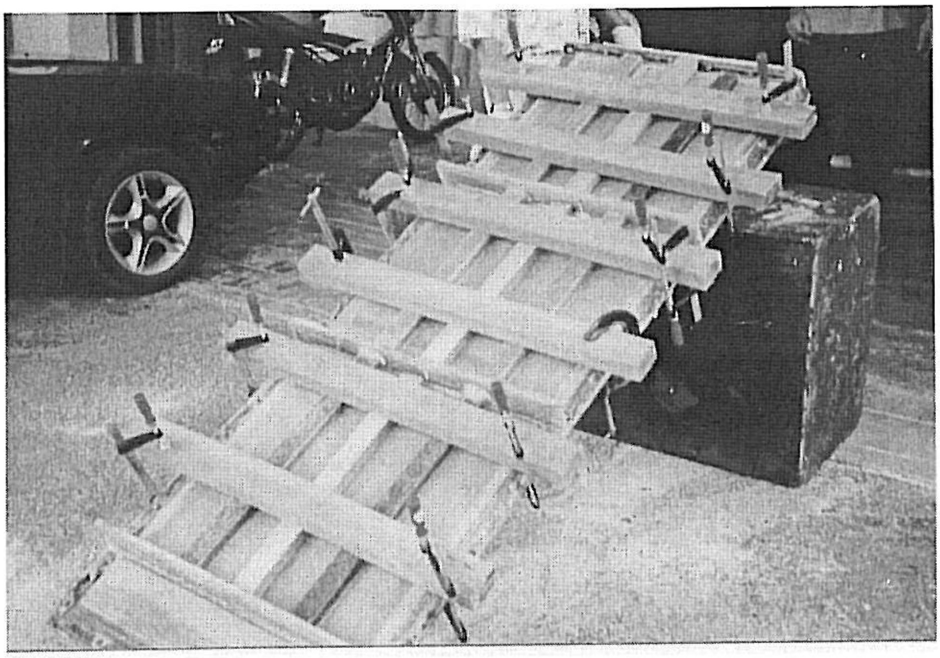


Figure 2.13 : Foam curing process.

The foam is left for one day to allow it to fully cured. But during the curing process, the foam is expanded from its initial size. The expansion put pressure to the mould and it happens that the mould unable to sustain the pressure causing it to crack as shown in Figure 2.14.

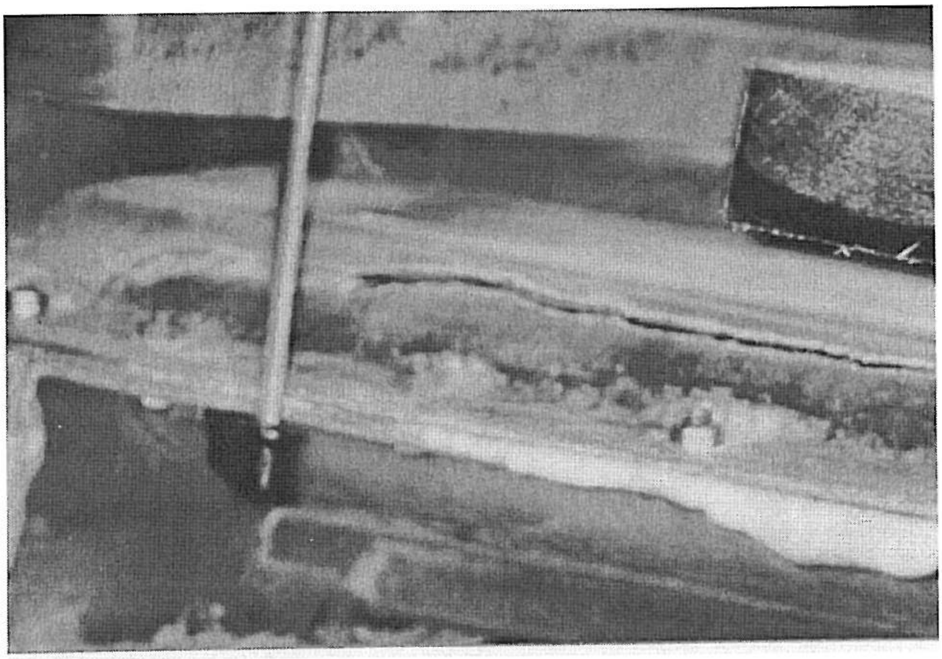


Figure 2.14 : Too much pressure can caused the mould to crack.

Once the foam is cured, the mould is again reused to fabricate the skin using fibre glass. Fibre glass is used as a test bed to see if the result either achieve the expectation or otherwise.

The result of the first test is given in Figure 2.15 below.

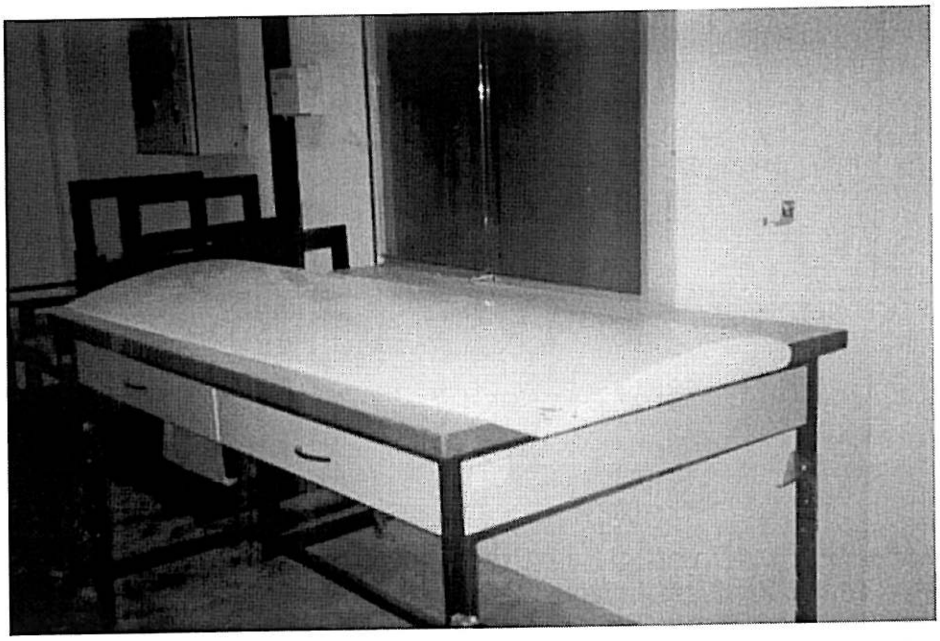


Figure 2.15 : Finished product fabricated using fibre glass, however inside is the foam.

Upon the completion of the product, it is found that the weight is far too heavy for use as aircraft wing (15 kg). The idea of using foam as to increase the stiffness of the wing is not realistic for aircraft application because it increasing the weight unnecessarily. Thick layer of fibre glass is found to be not suitable for aircraft application.

The result of the first attempt is not satisfactory and the search to find better solution continues. A meeting with one of Eagle Aircraft's engineering department has given the opportunity for me to explore another way how the Malaysian all-composite aircraft manufacturer using their expertise in composite material in aircraft structural fabrication.

## 2.8. Wing Fabricration At Eagle Aircraft (M) Sdn. Bhd.

After seeing difficulties to fabricate the wing using ordinary fibre glass technology, it was decided to explore deeper into the composite technology.

The best place to look into the technology that work closer to aerospace technology is Eagle Aircraft (M) Sdn. Bhd.

The company is a subsidiary of CTRM Sdn Bhd. Their primary product is all-composite two-seater multi-role aircraft. They have produced a number of them and their latest achievement is producing ARV for surveillance used.

## 2.9. Visit to Eagle

The first visit to Eagle was made to study the technology and method used to fabricate aircraft parts such as wing and fuselage. The reception is excellent and friendly.

They escort us to their fabrication shop and give detail explanation about the process from the mould and completed product.

These includes the visit to the wing fabrication shop, fuselage fabrication shop and also wing assembly workshop.

Eagle Aircraft agrees to help UTM in fabricating the wing with minimal fee. UTM will supply carbon veil, resin plus hardener and the mould.

The mould is send to Eagle Aircraft plant located at Batu Berendam, Melaka for the fabrication.

CHAPTER 3

Fabrication At Eagle Aircraft (M) Sdn. Bhd.

## 3.1 Introduction

The first thing is to prepare the mould. The mould needs to be cleaned from any dust and any type of debris. The surface is waxed and polished. Due to some abnormalities, the mould is modified to suit the fabrication process by Eagle. This includes more polishing the surfaces and smoothing rough edges. The whole process were carried out by experience technicians of Eagle.

## 3.2 Applying carbon veil

After mould preparation, it is time to apply carbon veil on the mould surface. The resin used is the one supplied by UTM. The ratio used is 100 to 34. The procedure is as follows

- Prepare the resin according the specified ratio.
- Apply mold release wax on to the mould surface. The wax is shown in figure below.


Figure 3.1 : The type of wax used as mold release wax.

Wet our the mould surface with a soft roller so that a thin uniform coat of resin is achieved. Sufficient resin should be applied so as to obtain a break free surface but not so that resins run out occur.

- Apply one ply of carbon veil to the wetted mould surface.
- Soft roller the veil cloth until it has been fully wetted. It is better to ensure the roller is dry to maximize resin removal. To know if the carbon is fully wetted out is when the surface exhibits a uniform, matt lustre. If polling occurs then soft roller the affected area to absorb the excess resin.
- If encountering tight radii, then "dab" the carbon veil with a soft bristled paint brush so that all signs of wrinkling and bridging are removed.
- Continue with lay up as defined by the drawings.

## 3.3 First Stage

It is best to explain by using the pictures in Figures below.

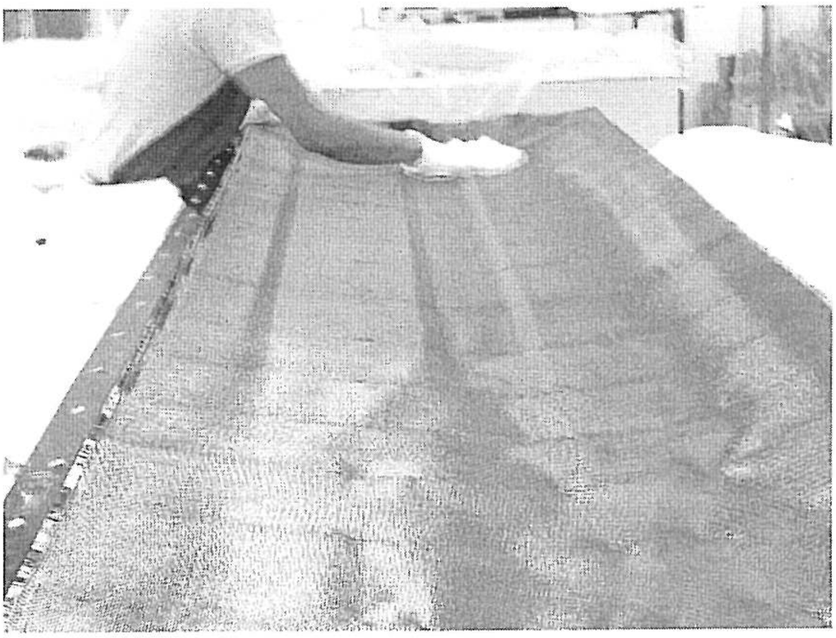


Figure 3.2 : Applying carbon veil on to the mould surface.

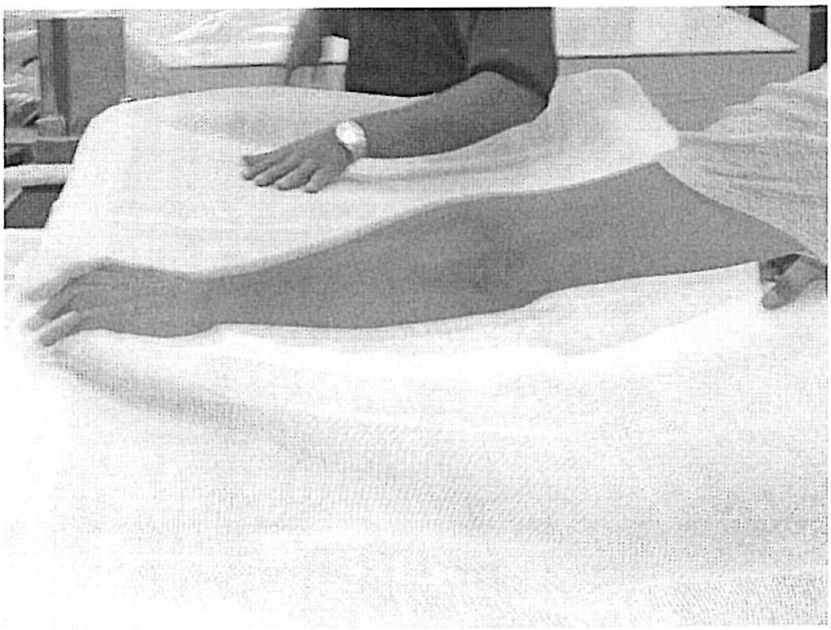


Figure 3.3 Applying bleeder

Figure 3.4 : Applying peel fly

Figure 3.5 : Applying release film

Figure 3.6 : Applying type 2 of release film

## 3.4 Second Stage

Next stage is the preparation to put foam core and second ply.

Figure 3.7 : Positioning the core stopper

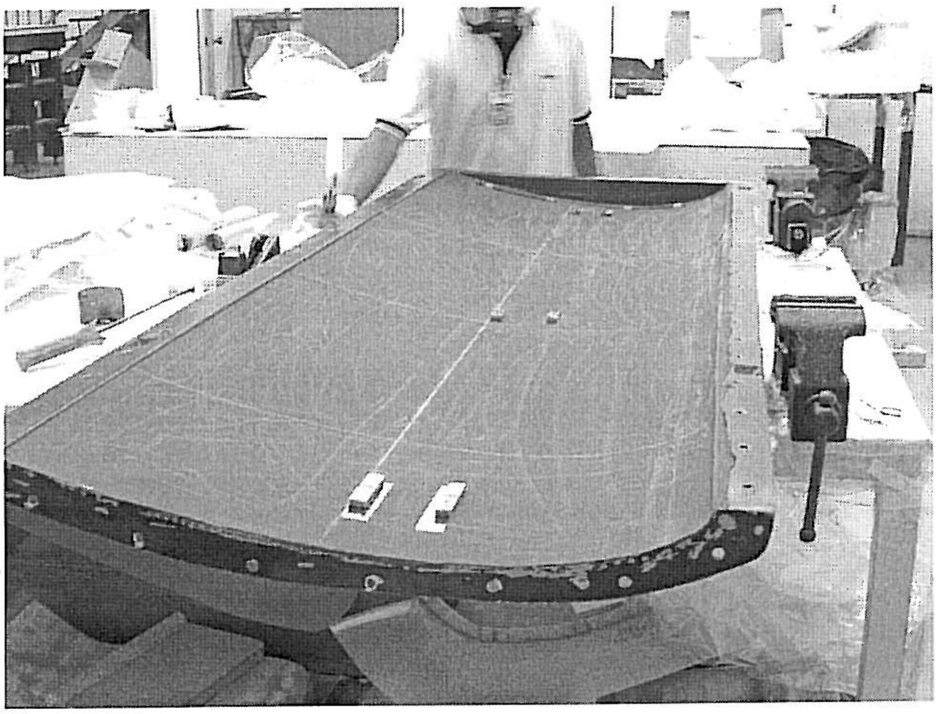


Figure 3.8: After first stage vacumn

Figure 3.9 : Beginning second stage lay-up

Figure 3.10 : Preparing for the second stage lay-up.

Figure 3.11 : Lying kevlar veil

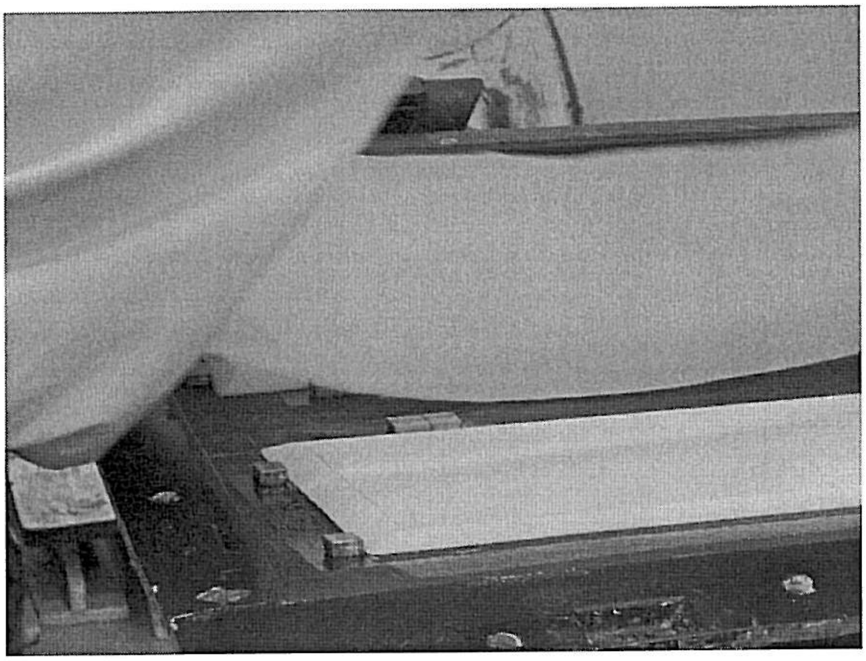


Figure 3.12 : Placing peel ply for second stage vacumn

Figure 3.13 : Inserting bondcore

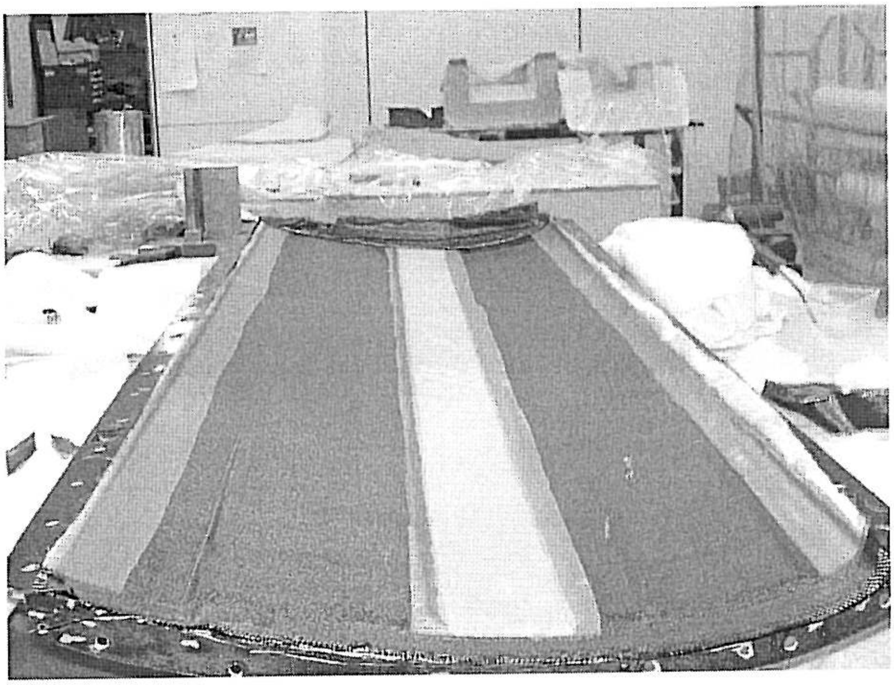


Figure 3.14 : Complete skin

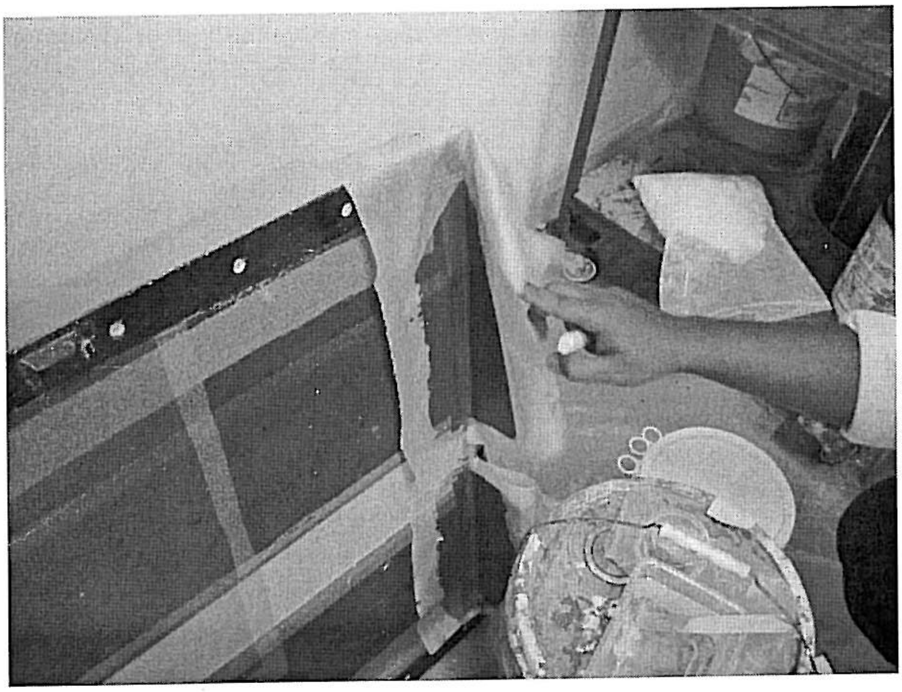


Figure 3.15 : Complete skin ready to be de-molded.

## 3.5 Demolding Processes

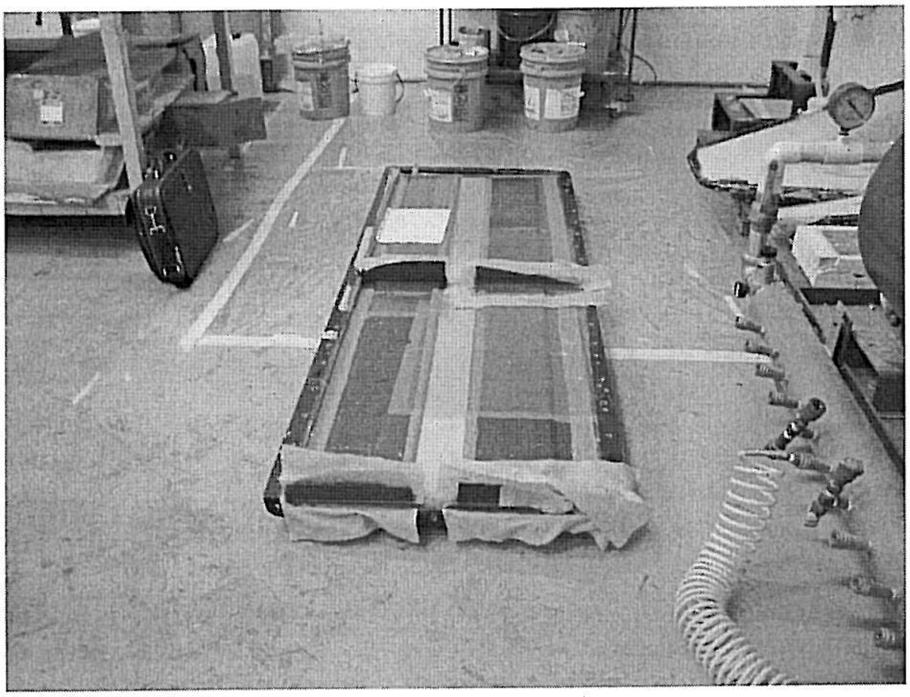


Figure 3.16 : Completed skin with ribs ready for demolding.

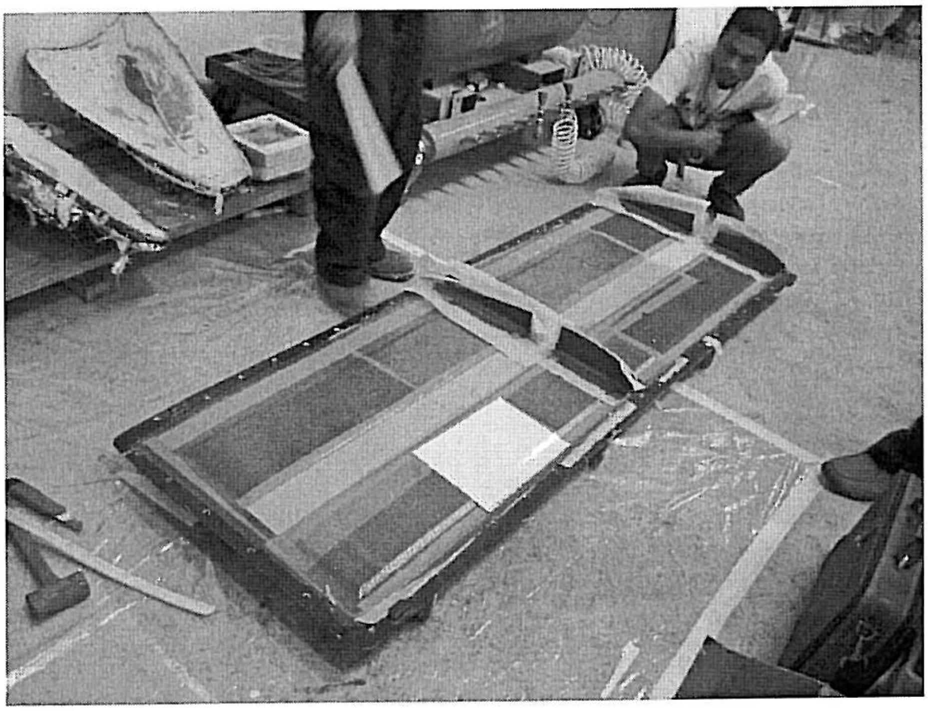


Figure 3.17 : About to start the demoulding process.

Figure 3.18 : Eagle's staff is demolding the skin.

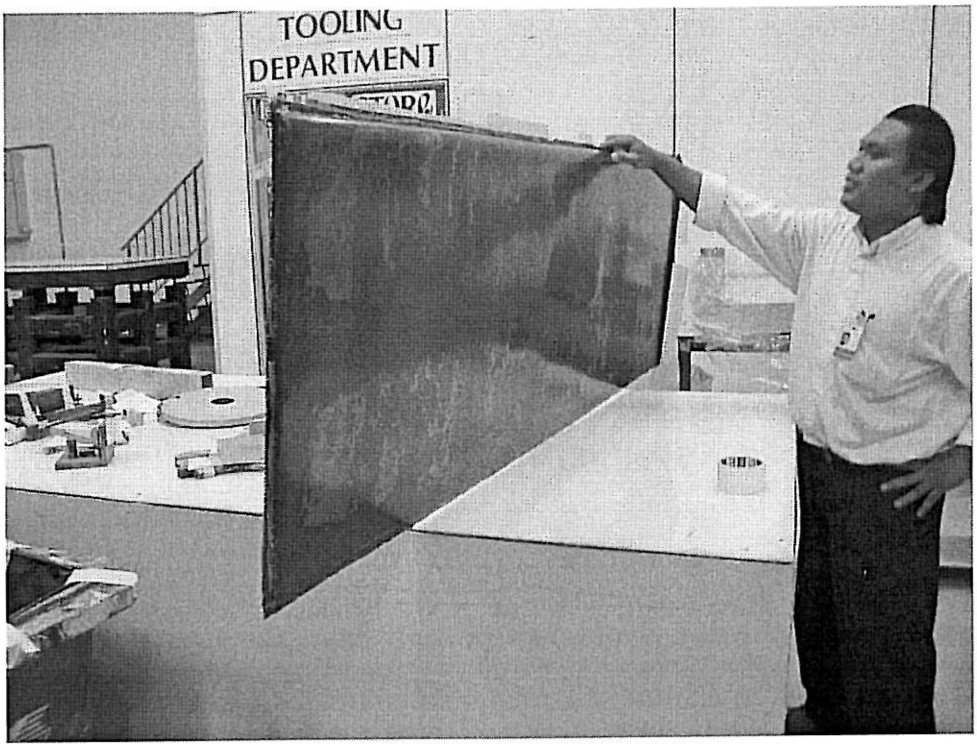



Figure 3.19 : After demolding, the smooth surface.

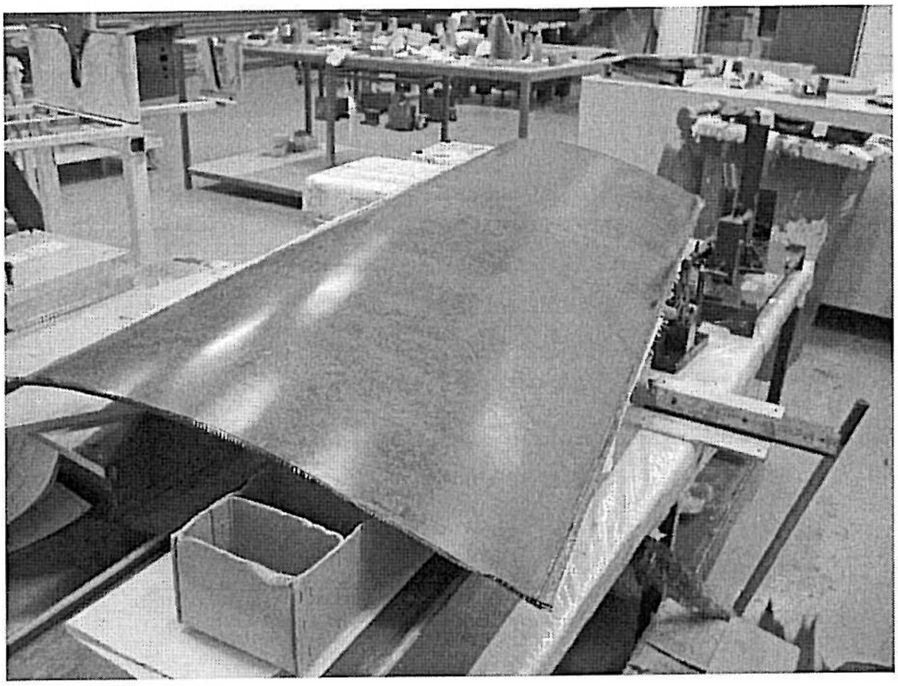


Figure 3.20 : Another view of the top surface of the wing.

Figure 3.21 : Peel plies still attaching the surface, waiting to be removed.

Figure 3.22 : Removing the peel ply and the trimming process is about to start.

Next stage is to bond top and lower skin to make a complete wing using carbon ply and QVA glue at the trailing edge.

## 3.6 Finished Product

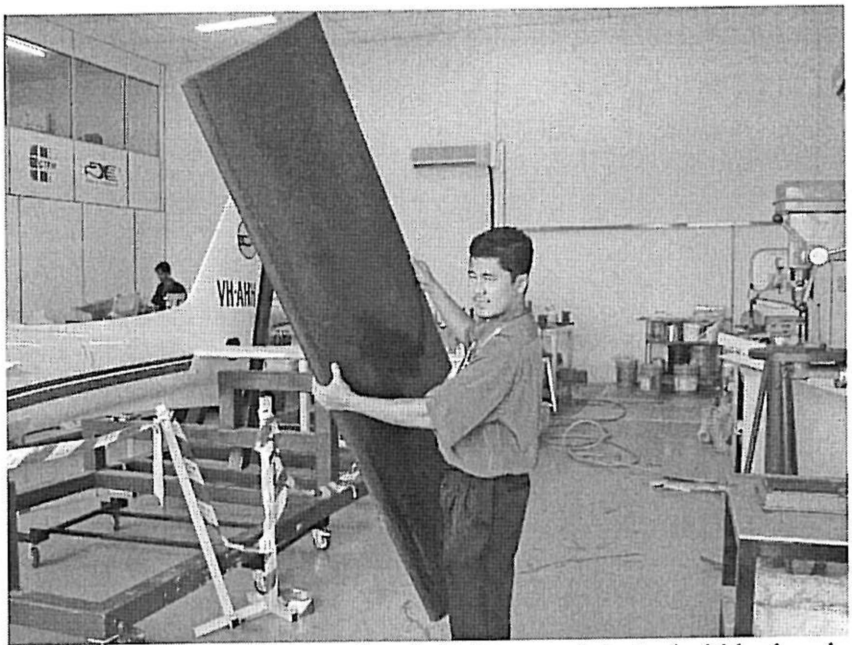


Figure 3.33 : Complete product is light enough to be hold by hand.

# CHAPTER 4

# DISCUSSION

## 4.1 Introduction

The selection of the type of airfoil and the wing span is based on the mathematical analysis based on various techniques outline by many authors. The next part is to make the real model.

The fabrication of UAV wing is found to be much more difficult that expected. There are several newly found items need to be considered in the project.

On paper design was done at the first stage to calculate the best type of airfoil and to predict the aerodynamic performance of the aircraft. This stage is rather easy to do since it only involve literature survey and study.

The selection of airfoil is done at this stage. The next stage is to figure out how to produce the wing using given airfoil type. There are many ways to fabricate a wing. The conventional way is to use metal and rivets. This traditional approach has its own advantage and disadvantage.

The primary advantage using the traditional method is the analysis of the strength of the structure is readily available in the literature. And even this method is taught in one of the subject of Bachelor Degree of Mechanical Engineering (Aeronautics). Thus the confidence in fabricating the wing is rather high.

In comparison, the fabrication of wing using composite material is relatively easy but the strength analysis is rather difficult.

UTM's Composite Center though have the capability to construct composite based structure, but it still does not have the adequate technology to be at par with any aviation composite manufacturers.

Thus, it is not efficient to fabricate wing without knowing exactly how the real aviation player construct their wing.

The best place to go is to Eagle Aircraft (M) Sdn. Bhd. Knowing their business, it is for sure the best way and most efficient method of constructing composite material is at their disposal.

Thus the project took a de tour. Instead fabricating the model in-house, let the Eagle experience help the construction but with supervision. There are new methods and approaches used in constructing aircraft structure using composite material that is not found in any textbook.

What we found out is that, the material used is very sensitive to the type of finishing one would expect.

UTM's supplied its own carbon veil and resins. Apparently the one that we gave was for mould preparation not product preparation. Thus, the consequences is the product hardened much quicker than Eagles's standard resin. It causes dryness on a few location on the surface. It is suggested that to use Eagle's resin to fabricate future wing.

Since the mould was not done by Eagle, the mould is a little bit too small for proper product fabrication. There should be adequate extension of flange at every edge of the mould to allow extra surface area meant for bonding purposes.

## 4.2 Conclusion

The one year project has reached its goal to find the best way to construct aircraft wing using composite material in the most efficient way. The knowledge can be used to start equipting the composite lab with proper tools for aircraft structure fabrication. Unfortunately, the last scope which is to run a structural tests is yet to be done due to financial constraint.

The next project is to build the fuselage and the full span spar. Example of spar is show in Figure 4.1 and 4.2.

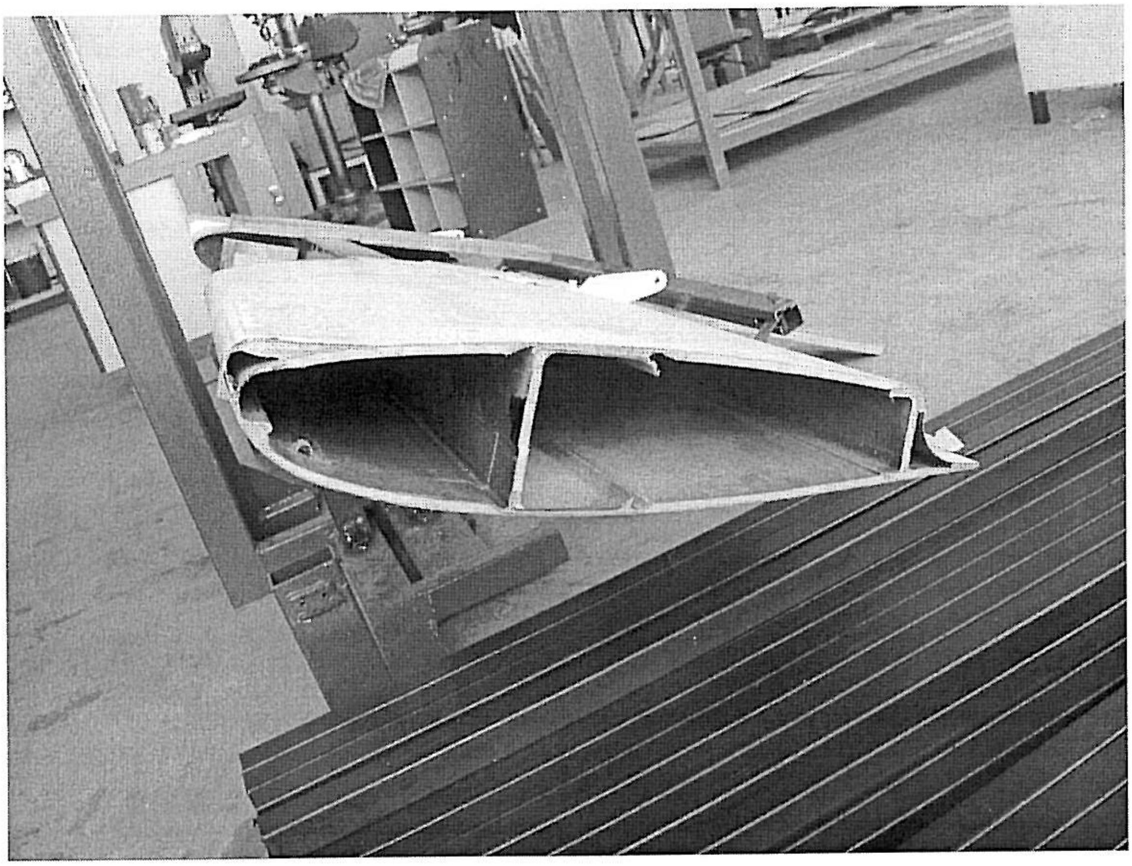


Figure 4.1 : Example of spar, this is one of Eagle's structural element.

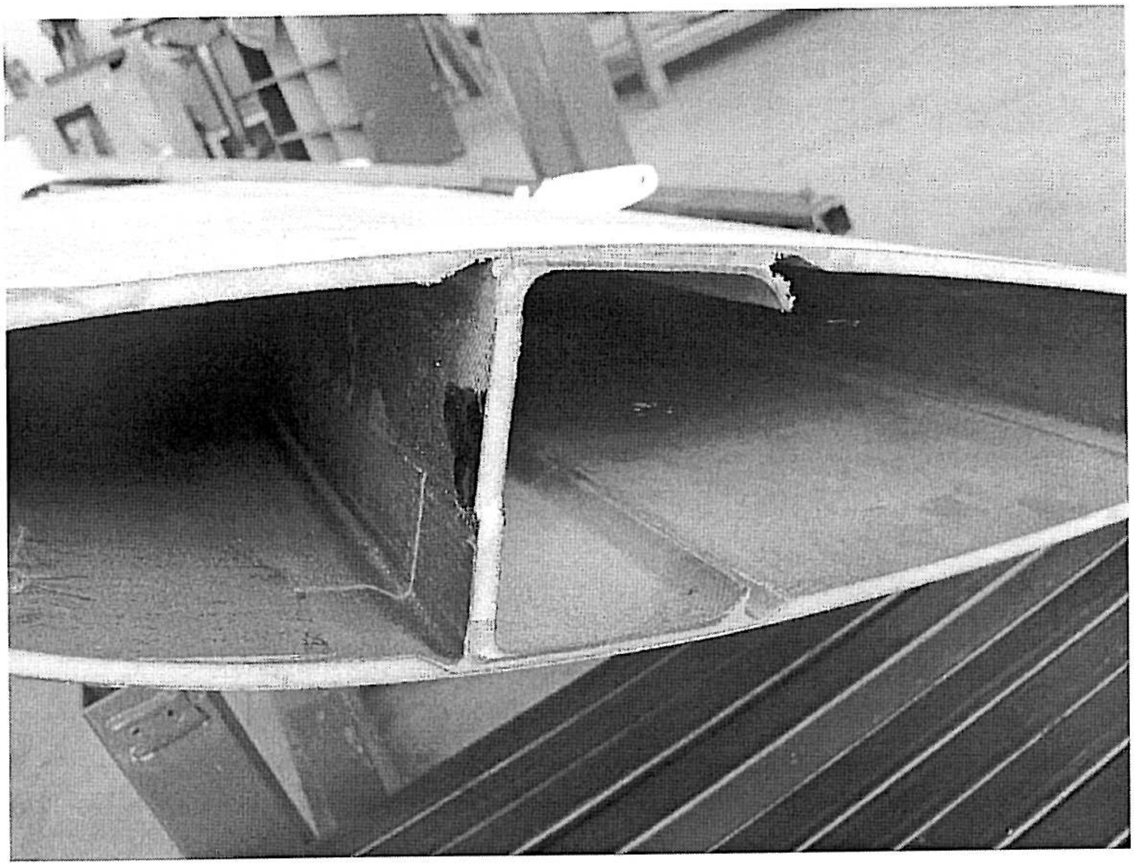
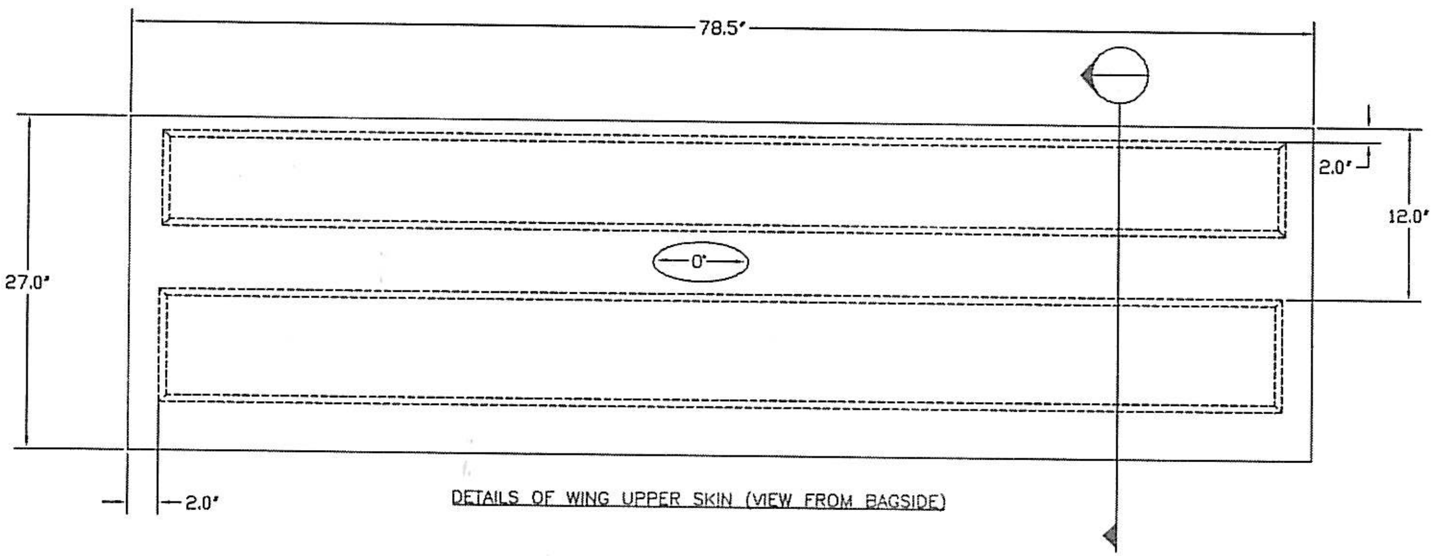
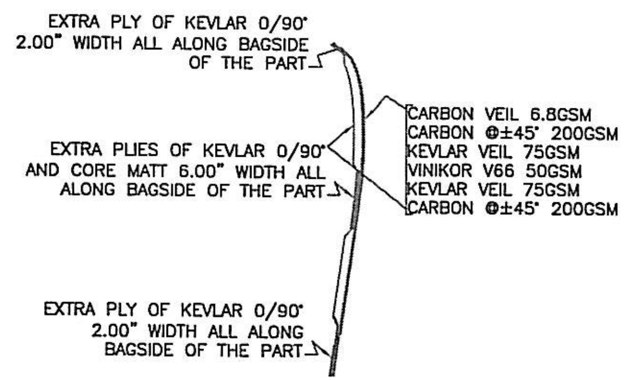


Figure 4.2 A closer look to the spar element. Take note on the web, the middle white material is vinicore. The composite material is only used at the skin.

# APPENDICES




DETAILS OF WING UPPER SKIN (VIEW FROM BAGSIDE)



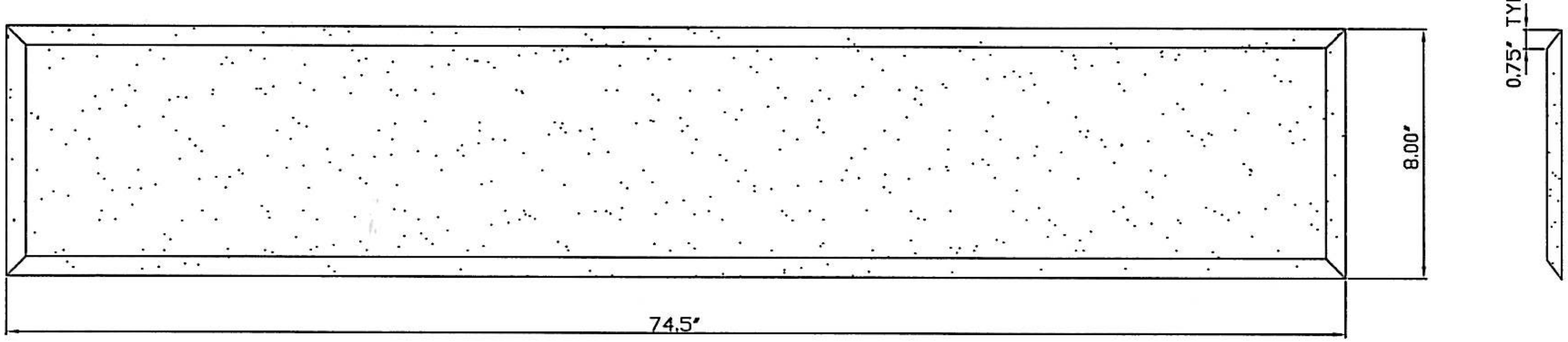

SECTION F

UTM PROJECT
WING UPPER SKIN

N.T.S A3 UTM0001 1 1

## DRAWING CHANGES

| REV | CHANGE NOTICE | DATE | REVISION DESCRIPTION / REASON | APPROVED BY | BY |
|---|---|---|---|---|---|
| | | | | | |




NOTE:
1. MANUFACTURE 4 UNIT OF CORE USING VINIKOR V66 0.25"
2. PUNCH THE CORE AS PER EPS 04-023
3. CORE MAY CONSIST OF 2 PIECES JOINED TOGETHER USING THIXOGLUE PER MPM 05-001

| | |
|---|---|
| NEXT ASSEMBLY | |
| AS 1100 Third Angle Projection | TOLERANCE [Except where otherwise stated]: 1 DECIMAL PLACES (X.X") ± 0.100"; 2 DECIMAL PLACES (X.XX") ± 0.030"; 3 DECIMAL PLACES (X.XXX") ± 0.010"; ANGULAR TOLERANCE ±1.0° |

| | | |
|---|---|---|
| DESIGNED | EAM | 23-10-03 |
| DRAWN | IZHAR HARUN | 23-10-03 |
| DWG CHK | | |
| ENG CHK | | |
| WEIGHT | | |
| STRESS | | |
| PROJECT | | |
| DO NOT SCALE FROM DRAWING | | |


EAGLE AIRCRAFT [194035-K]
Locked Bag 1028, Melaka 75150, Malaysia Phone (606) 317 1003 Fax (606) 317 7023


Title: UTM PROJECT CORE DRAWING



| Scale | Sheet Size | Drawing Number | Sheet | of | Rev. |
|---|---|---|---|---|---|
| N.T.S | A3 | UTM0004 | 1 | 1 | 1 |

Cad File Name – .DWG

| DRAWING CHANGES | | | | | |
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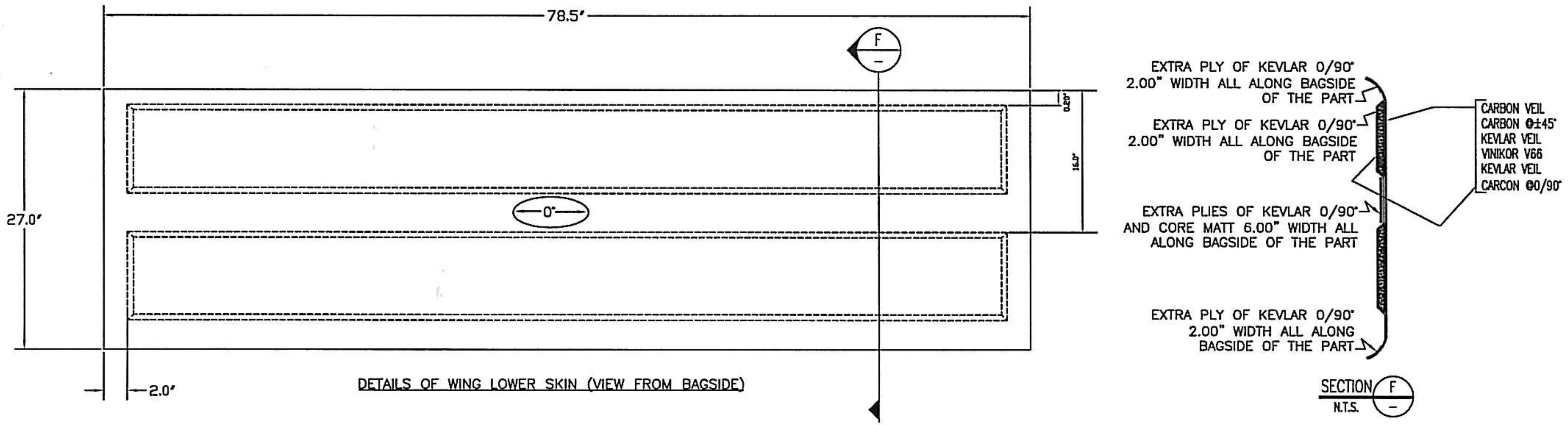


NOTE:
1. USE PROVIDED UTM MOULD
2. MANUFACTURE PART AS PER EPS 04-001
3. USE PROVIDED EPOXY RESIN
4. KEVLAR VEIL WILL ONLY BE USED ON CORE SURFACE
5. PREPARE AREA ON KEVLAR LOCATION ONLY PRIOR TO BONDING
6. IDENTIFY PART AS 'UTM RPV LOWER SKIN' AS PER EPS 10-001 CLASS 1

NEXT ASSEMBLY

AS 1100

Third Angle Projection

TOLERANCE (Except where otherwise stated):

| | |
|---|---|
| 1 DECIMAL PLACES (X.X") | ± 0.100" |
| 2 DECIMAL PLACES (X.XX") | ± 0.030" |
| 3 DECIMAL PLACES (X.XXX") | ± 0.010" |
| ANGULAR TOLERANCE | ±1.0° |

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| DESIGNED | EAM | 23-10-03 |
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| WEIGHT | | |
| STRESS | | |
| PROJECT | | |

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Title UTM PROJECT
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| Scale | Sheet Size | Drawing Number | Sheet | of | Rev. |
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| N.T.S | A3 | UTM0002 | 1 | | 1 |

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